Estimating Log-Making Costs in the Central States

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Logging costs make up a significant part of the total cost of producing wood products. If logging costs could be lowered, it might mean greater profits for the logger and lower prices for the consumer.

As a step toward finding ways to control and reduce logging costs, a study was made in southern Illinois to (1) determine how each of the log-making[1] activities was affected by variables such as tree size, species, volume cut per acre, topography, crew size,

[1]The term "log-making," as used here, includes traveling between the trees to be cut, felling the trees, limbing them, and bucking the boles into log-lengths.

and type of powersaw used; and (2) to provide basic production data for use in developing logging plans and cost estimates for specific logging jobs. Results showed that, within the range of conditions studied, log-making was more efficient with one-man crews than with two-man crews, and production increased with tree size and volume cut per acre. Topography, tree species, and type of powersaw did not significantly affect production rates. This information led to the development of a practical method for estimating log-making costs.

The Study

This study was made on the Kaskaskia Experimental Forest located in southern Illinois within the boundaries of the Shawnee National Forest. The forests are upland hardwoods of the oak-hickory and mixed-hardwood types consisting principally of black oak, white oak, northern red oak, scarlet oak, yellow-poplar, and several upland hickories.[2]

One- or two-man crews using either reduction- or direct-drive saws are common in Central States logging operations. In conducting the study, one- and two-man crews with Homelite Model 6-22 reduction-drive and Model EZ-6 direct-drive saws felled and bucked approximately 242,000 board feet of timber in 27 randomly assigned areas. Both saws had diaphragm carburetors which permitted operation regardless of saw position. The direct-drive saw had a 21-inch guide bar and the reduction-drive saw had a 23-inch guide bar. Neither saw was equipped with a tailstock or handlebars.

Before the study began, the crews were trained to a level of proficiency considered by a team of Forest Service technologists and a representative of the chain saw manufacturer to be equivalent to that of the better commercial logging crews in the region. During the study both saws were maintained according to standards developed by the saw manufacturer.

Volume cut per acre in the study ranged from 630 to 4,300 board feet and averaged 1,840 board feet.[3] The trees cut ranged in size

[2]Common names according to Little, Elbert L., Jr. Check list of native and naturalized trees of the United States (including Alaska), U.S. Dept. Agr. Handb. 41, 472 pp. 1953.

[3]International ¼-inch log scale (gross) is used throughout this report.

from 10 to 36 inches in diameter and from 8 to 96 feet in merchantable height. Average volume per tree was approximately 215 board feet. The ranges in volume per acre and size of trees cut were similar for all equipment/crew-size combinations studied.

Stumps were cut at 1-foot heights, or as near that height as practicable, and the crews attempted to control the direction of fall of each tree to minimize damage to the residual stand and to facilitate skidding. Bucking was done to recover the best combination of factory-grade logs available from the trees.[4]

Chains on both types of saws had planer-type teeth. Each chain was used until it would no longer cut satisfactorily after field sharpening. It was then replaced by a new chain of the same type. In addition to a saw, each crew carried fuel and oil for a full day's operation, one extra sparkplug, one extra sharpened chain, one chain file and file guide, one chain saw tool kit, two magnesium wedges, one pole ax, and a measuring stick. Each morning the crew chief inspected the equipment to be used to assure proper mechanical condition and operating performance.

Log-making crews performed the following tasks, as nearly as possible in the order listed:

- Determined felling direction of tree to be cut.
- Cleared brush for felling.
- Prepared and started saw.
- Made undercut.
- Made backcut, wedging as needed.
- Limbed felled tree.
- Marked bole for bucking.
- Made bucking cuts, wedging as needed.
- Located next tree to cut.
- Collected tools and traveled to next tree.

[4]For a discussion of the importance of stump height and careful bucking in hardwood logging see Whitmore, Roy A., Jr., and Jackson, Willard L. Increase your profit in the woods. U.S. Forest Serv. Cent. States Forest Expt. Sta. Tech. Paper 151, 10 pp., illus. 1956.

For the two-man crews one man was designated as crew chief. He supervised the operation, decided on the order the trees would be cut, and specified the felling direction for each tree. Otherwise the tasks were divided: while one man operated the saw, the other man was cutting brush, limbing, wedging, or marking the bole for bucking. Assignments were rotated frequently to minimize fatigue. The objective was to keep both men and the saw working productively as much of the time as possible.

Throughout the study, a technologist accompanied the log-making crews to record production time and related data. He remained in the background, however, and did not advise, supervise, or interfere with the crews. For each tree cut, species, diameter, merchantable height, basal area, slope of adjacent land, gross and net volume of logs produced, and similar data were recorded. For each saw a record was kept of fuel and oil consumption. Each of the following activities was timed with a decimal-minute stopwatch:

1. *Travel.* — This began when a crew left a previously felled and bucked tree and ended when felling began at the next tree. The time needed to gather up tools and deposit them at the next tree was included.

2. *Felling.* — This included "swamping" around a tree to be felled, making the undercut and backcut, and wedging. Felling time ended when the tree was on the ground and the limbing or marking was started.

3. *Limbing and marking.* — This consisted of removing limbs, stubs, and other protrusions from the tree stem, and marking the stem into log lengths. It ended when the merchantable bole had been limbed and marked for bucking into logs.

4. *Bucking.* — This began when the limbing and marking was completed and ended when the last bucking cut was completed.

5. *Maintenance.* — This was time spent in servicing the saw on the job. It included refueling and oiling, filing and repairing the chain, cleaning, and making adjustments to the power unit and chain.

6. *Rest.* — This was time taken for a periodic break or other purpose.

Associated with each of the first four items above were varying amounts of delay time. Examples of delays were searching for the next tree to be felled, freeing a lodged tree, and loosening a pinched saw.

Results

One-Man Crews More Efficient Than Two-Man Crews

For most log-making activities, production by the two-man crews exceeded that of the one-man crews, but the difference was never as much as 2 to 1. Thus, the one-man crews were consistently more efficient in terms of man-minutes expended per thousand board feet of logs produced. Total log-making time averaged approximately 60 man-minutes per thousand board feet for the one-man crews, and 98 man-minutes for the two-man crews.[5] The breakdown of these times by log-making activity is as follows:

	Man-minutes per thousand board feet	
	One-man crews	*Two-man crews*
Travel between trees	3.88	6.44
Felling	11.96	23.92
Limbing and marking	12.71	13.62
Bucking	9.62	19.24
Maintenance	12.00	17.84
Rest	10.33	16.80
Total	60.50	97.86

These times include delays averaging approximately 11 man-minutes per thousand board feet cut by one-man crews, and 22 man-minutes per thousand board feet cut by two-man crews.

Total log-making time varied with tree size and volume cut per acre, but production per man-hour with one-man crews always exceeded that of two-man crews by 60 to 65 percent. For all equipment/crew and tree-size/intensity-of-cut combinations studied, approximately 30 percent of the time required for travel,

[5]These times are for the average conditions of tree size, tree spacing, and cut per acre found in the study, which were as follows: Average tree diameter at breast height, 19.2 inches; average merchantable height, 26 feet; average number of trees harvested per acre, 8.6 trees; and average volume cut per acre, 1,840 board feet gross scale.

felling, limbing and marking, and bucking was spent in assembling or moving tools and equipment, swamping, or otherwise preparing for the job to be done. The three activities of felling (fig. 1), limbing and marking (fig. 2), and bucking (fig. 3) consistently made up 50 to 60 percent of the total time required for the entire log-making operation.

About half the maintenance time was spent filing or repairing the saw chain, 35 to 40 percent on cleaning the saw, and the remainder on refueling and miscellaneous care of the saw and other equipment.

Production Rates and Costs Were Not Affected By Type of Saw, Species, or Topography

The study showed no significant difference in rate of production, consumption of fuel or chain oil, or saw maintenance requirements among species or slopes, or between saw types. Performance of both types of saws was excellent throughout the study. After being trained on both, the operators showed no preference for one saw type over the other for all-around use. They liked the lighter weight of the direct-drive saw and, because it did not pull into the cut, they preferred it for limbing. Conversely, the operators liked the lugging power of the reduction-drive saw, especially for bucking. Fuel, engine oil, and chain oil costs per thousand board feet of timber felled and bucked were as follows:

	Cost per thousand board feet
Gasoline[1]	$0.039
Engine oil[2]	.056
Chain oil[3]	.020
Total	$0.115

[1]Bulk, non-highway use, cost per gallon — $0.20.
[2]Cost per quart — $0.75.
[3]Cost per quart — $0.20.

The study did not continue long enough to obtain reliable information on such costs as interest on the equipment investment, rate of depreciation, and replacement parts or major repairs.

Although the steeper slopes seemed to make footing more difficult for the log-making crews and slowed their rates of production,

FIGURE 1.—Felling with one-man powersaw.

FIGURE 2. — Limbing tree and marking bole for bucking with a two-man crew.

FIGURE 3. — Bucking bole into logs with two-man crew: One man saws while the other clears away brush and limbs.

FIGURE 4. — Traveling between trees with felling and bucking equipment.

other factors apparently compensated for this so that production rates on gentle and steep slopes were nearly equal. For example, where the slopes were gentle, as in the coves and draws, the crews were frequently slowed by dense undergrowth; but where the slopes were steep enough to make the footing bothersome, underbrush was seldom a problem.

Production Increased as Tree Size and Volume Cut per Acre Increased

For both one- and two-man crews, rates of log-making increased with tree size and number of trees cut per acre. The average distance between trees to be harvested — and thus the time required for log-making crews to travel between trees (fig. 4) — was naturally least for those tracts where the number of trees to be cut per acre was largest (tables 1 and 2).[6] Similarly, for a given number of trees to cut per acre, crew travel time per thousand board feet was less for tracts where large trees were cut than for tracts where the trees cut were small.

For felling, limbing and marking, and bucking, crew times required per thousand board feet produced decreased as the trees harvested increased in diameter and/or height (tables 3 and 4).[7] For example, one-man-crew felling time per thousand board feet was 48 percent greater, limbing and marking time was 63 percent greater, and bucking time was 36 percent greater for 18-inch, 2-log trees than for 26-inch, 2-log trees.

As would be expected, tree height differences had an especially important effect on felling time per thousand board feet. One-man-crew felling time per thousand board feet for 18-inch, 1-log trees averaged 130 percent greater than for 18-inch, 3-log trees. The same difference in height had less effect on limbing and marking, and bucking time (average increases of 27 percent and 35 percent, respectively).

[6]Travel time was found to be directly proportional to the distance between the trees harvested, averaging 1.145 $\pm$0.021 crew-minutes, and 0.952 $\pm$0.016 crew-minutes per 100 feet (at one standard deviation), respectively, for one-man and two-man crews. Tables 1 and 2 were developed by applying these rates of travel to the various cuts per acre shown, assuming uniform spacing of the trees harvested.

[7]The times required to fell, limb and mark, and buck were all found to be directly proportional to the basal area of the trees harvested. The times were also related to the merchantable height of the trees, but not consistently so. Totals of these times per tree (exclusive of travel time) ranged from 3 to 11 minutes and averaged nearly 8 minutes.

TABLE 1.—Travel time between trees for one-man log-making crews, by number of trees and volume cut per acre

(Crew-minutes per thousand board feet)

Trees cut per acre (number)	Average distance between trees (feet)	Average board-foot volume cut per acre[1/] [2/]											
		500	1,000	1,500	2,000	2,500	3,000	3,500	4,000	4,500	5,000	5,500	6,000
1	208.7	4.78	2.39										
2	147.6	6.76	3.38	2.25	1.69								
3	120.5	8.28	4.14	2.76	2.07	1.66	1.38						
4	104.4	9.56	4.78	3.19	2.39	1.91	1.59	1.37	1.20				
5	93.3	10.68	5.34	3.56	2.67	2.14	1.78	1.53	1.34	1.19	1.07		
6	85.2		5.85	3.90	2.93	2.34	1.95	1.67	1.46	1.30	1.17	1.06	0.98
7	78.9		6.32	4.22	3.16	2.53	2.11	1.81	1.58	1.41	1.26	1.15	1.05
8	73.8		6.76	4.51	3.38	2.70	2.25	1.93	1.69	1.50	1.35	1.23	1.13
9	69.6		7.17	4.78	3.59	2.87	2.39	2.05	1.79	1.59	1.43	1.30	1.20
10	66.0		7.56	5.04	3.78	3.02	2.52	2.16	1.89	1.68	1.51	1.37	1.26
11	62.9			5.28	3.96	3.17	2.64	2.26	1.98	1.76	1.58	1.44	1.32
12	60.2			5.51	4.14	3.31	2.76	2.36	2.07	1.84	1.65	1.50	1.38
13	57.9			5.75	4.31	3.45	2.87	2.46	2.15	1.92	1.72	1.57	1.44
14	55.8			5.96	4.47	3.58	2.98	2.56	2.24	1.99	1.79	1.63	1.49
15	53.9			6.17	4.63	3.70	3.09	2.64	2.31	2.06	1.85	1.68	1.54
16	52.2				4.78	3.82	3.19	2.73	2.39	2.12	1.91	1.74	1.59
17	50.6				4.92	3.94	3.28	2.81	2.46	2.19	1.97	1.79	1.64
18	49.2				5.07	4.06	3.38	2.90	2.53	2.25	2.03	1.84	1.69
19	47.9				5.21	4.17	3.47	2.98	2.60	2.32	2.08	1.89	1.74
20	46.7				5.35	4.28	3.56	3.06	2.67	2.38	2.14	1.94	1.78
21	45.5					4.38	3.65	3.13	2.73	2.43	2.19	1.99	1.82
22	44.5					4.48	3.74	3.20	2.80	2.49	2.24	2.04	1.87
23	43.5					4.58	3.82	3.27	2.86	2.55	2.29	2.08	1.91
24	42.6					4.68	3.90	3.34	2.93	2.60	2.34	2.13	1.95
25	41.7					4.77	3.98	3.41	2.98	2.65	2.39	2.17	1.99
30	38.1						4.36	3.74	3.27	2.91	2.62	2.38	2.18
35	35.3							4.04	3.54	3.14	2.83	2.57	2.36
40	33.0								3.78	3.36	3.02	2.75	2.52
45	31.1									3.56	3.20	2.91	2.67
50	29.5										3.38	3.07	2.81
55	28.1											3.22	2.95
60	26.9												3.08

1/ Gross scale International 1/4-inch Log Rule.

2/ To compute travel time per thousand board feet for volumes other than at 500 board foot intervals shown use the following equation:

$$\frac{11.449 \times \text{Average distance between trees in feet} \times \text{Number of trees to cut per acre}}{\text{Board-foot volume to cut per acre}}$$

Example - What is the travel time per thousand board feet for one man if he is to cut 14 trees per acre which contain a total volume of 3,800 board feet?

$$\frac{11.449 \times 55.8 \times 14}{3,800} = 2.35 \text{ crew-minutes}$$

TABLE 2.—Travel time between trees for two-man log-making crews, by number of trees and volume cut per acre

(Crew-minutes per thousand board feet)

Trees cut per acre (number)	Average distance between trees (feet)	Average board-foot volume cut per acre[1/] [2/]											
		500	1,000	1,500	2,000	2,500	3,000	3,500	4,000	4,500	5,000	5,500	6,000
1	208.7	3.97	1.99										
2	147.6	5.62	2.81	1.87	1.41								
3	120.5	6.88	3.44	2.29	1.72	1.38	1.15						
4	104.4	7.95	3.98	2.65	1.99	1.59	1.33	1.14	0.99				
5	93.3	8.88	4.44	2.96	2.22	1.78	1.48	1.27	1.11	0.99	0.89		
6	85.2		4.87	3.24	2.43	1.95	1.62	1.39	1.22	1.08	0.97	0.88	0.81
7	78.9		5.26	3.51	2.63	2.10	1.75	1.50	1.31	1.17	1.05	0.96	0.88
8	73.8		5.62	3.75	2.81	2.25	1.87	1.61	1.41	1.25	1.12	1.02	0.94
9	69.6		5.96	3.98	2.98	2.39	1.99	1.70	1.49	1.33	1.19	1.08	0.99
10	66.0		6.28	4.19	3.14	2.51	2.09	1.80	1.57	1.40	1.26	1.14	1.05
11	62.9			4.39	3.29	2.63	2.20	1.88	1.65	1.46	1.32	1.20	1.10
12	60.2			4.58	3.44	2.75	2.29	1.96	1.72	1.53	1.38	1.25	1.15
13	57.9			4.78	3.58	2.87	2.39	2.05	1.79	1.59	1.43	1.30	1.19
14	55.8			4.96	3.72	2.97	2.48	2.12	1.86	1.65	1.49	1.35	1.24
15	53.9			5.13	3.85	3.08	2.57	2.20	1.92	1.71	1.54	1.40	1.28
16	52.2				3.98	3.18	2.65	2.27	1.99	1.77	1.59	1.45	1.33
17	50.6				4.09	3.28	2.73	2.34	2.05	1.82	1.64	1.49	1.36
18	49.2				4.22	3.37	2.81	2.41	2.11	1.87	1.69	1.53	1.41
19	47.9				4.33	3.47	2.89	2.48	2.17	1.93	1.73	1.58	1.44
20	46.7				4.45	3.56	2.96	2.54	2.22	1.98	1.78	1.62	1.48
21	45.5					3.64	3.03	2.60	2.27	2.02	1.82	1.65	1.52
22	44.5					3.73	3.11	2.66	2.33	2.07	1.86	1.69	1.55
23	43.5					3.81	3.17	2.72	2.38	2.12	1.90	1.73	1.59
24	42.6					3.89	3.24	2.78	2.43	2.16	1.95	1.77	1.62
25	41.7					3.97	3.31	2.84	2.48	2.21	1.98	1.80	1.65
30	38.1						3.63	3.11	2.72	2.42	2.18	1.98	1.81
35	35.3							3.36	2.94	2.61	2.35	2.14	1.96
40	33.0								3.14	2.79	2.51	2.28	2.09
45	31.1									2.96	2.66	2.42	2.22
50	29.5										2.81	2.55	2.34
55	28.1											2.68	2.45
60	26.9												2.56

1/ Gross scale International 1/4-inch Log Rule.

2/ To compute travel time per thousand board feet for volumes other than at 500 board foot intervals shown use the following equation:

$$\frac{9.52 \times \text{Average distance between trees in feet} \times \text{Number of trees to cut per acre}}{\text{Board foot volume to cut per acre}}$$

Example - What is the travel time per thousand board feet for two-man crews cutting 14 trees per acre which contain a total volume of 3,800 board feet?

$$\frac{9.52 \times 55.8 \times 14}{3{,}800} = 1.96 \text{ crew-minutes (or 3.92 man-minutes)}$$

TABLE 3.—Felling, limbing and marking, and bucking time for one-man crews, by tree diameter and height

(Crew-minutes per thousand board feet)

Diameter breast height (inches)	Merchantable height in 16-foot logs							
	1/2	1	1 1/2	2	2 1/2	3	3 1/2	4
12	102.20	76.84	67.96					
13	92.16	68.42	59.00					
14	85.28	62.47	53.38	48.02				
15	80.38	56.72	47.93	42.76				
16	76.10	52.52	44.00	38.99	36.87			
17	72.47	49.11	40.66	35.89	33.56			
18	69.40	46.37	38.07	33.43	31.08	29.43		
19	66.62	43.85	35.79	31.09	28.72	26.97		
20	64.09	41.88	33.86	29.23	26.90	25.19	24.61	
21		40.10	32.01	27.45	25.16	23.48	22.76	
22		38.61	30.60	26.08	23.78	22.10	21.33	20.73
23		37.42	29.48	25.02	22.67	20.95	20.21	19.60
24		36.30	28.41	24.03	21.71	19.96	19.17	18.52
25		35.38	27.52	23.13	20.77	19.03	18.27	17.61
26		34.49	26.69	22.30	19.98	18.27	17.42	16.74
27		33.77	25.99	21.63	19.27	17.57	16.74	16.05
28		33.08	25.35	21.01	18.66	16.99	16.13	15.44
29		32.49	24.79	20.46	18.10	16.43	15.56	14.86
30		31.91	24.26	19.93	17.57	15.91	15.02	14.30
31		31.37	23.74	19.44	17.09	15.40	14.52	13.79
32		30.88	23.29	19.03	16.65	14.97	14.04	13.31
33		30.45	22.90	18.63	16.27	14.61	13.67	12.94
34		30.06	22.53	18.28	15.93	14.28	13.33	12.58
35		29.71	22.18	17.96	15.63	14.02	13.01	12.26
36		29.47	21.90	17.70	15.34	13.89	12.71	11.97

Discussion and Application of Results

The data developed in this study and included in tables 1 through 4 provide the basic information needed for estimating log-making costs and rates of production for specific Central States hardwood stands. To expedite the use of these tables for compiling log-making cost estimates a *Log-Making Appraisal Work Sheet* has been devised. The use of the Appraisal Work Sheet is illustrated in the following example:

TABLE 4.—Felling, limbing and marking, and bucking time for two-man crews, by tree diameter and height

(Crew-minutes per thousand board feet)

Diameter breast height (inches)	Merchantable height in 16-foot logs							
	1/2	1	1 1/2	2	2 1/2	3	3 1/2	4
12	85.81	63.54	55.57					
13	77.63	56.75	48.41					
14	72.01	51.94	43.93	39.20				
15	68.00	47.32	39.58	35.02				
16	64.51	43.93	36.44	32.03	30.09			
17	61.53	41.18	33.77	29.57	27.47			
18	59.02	38.95	31.69	27.62	25.52	24.02		
19	56.74	36.93	29.88	25.75	23.64	22.08		
20	54.66	35.33	28.32	24.28	22.20	20.68	20.10	
21		33.90	26.84	22.85	20.81	19.32	18.65	
22		32.70	25.71	21.76	19.72	18.24	17.52	16.96
23		31.74	24.81	20.92	18.85	17.32	16.64	16.07
24		30.84	23.95	20.14	18.08	16.54	15.84	15.22
25		30.09	23.24	19.42	17.34	15.81	15.11	14.50
26		29.37	22.58	18.75	16.71	15.21	14.44	13.82
27		28.79	22.02	18.22	16.15	14.65	13.90	13.28
28		28.23	21.52	17.72	15.65	14.19	13.42	12.79
29		27.75	21.06	17.28	15.21	13.76	12.97	12.33
30		27.29	20.63	16.86	14.79	13.35	12.53	11.89
31		26.85	20.21	16.47	14.41	12.94	12.14	11.49
32		26.45	19.85	16.13	14.05	12.59	11.76	11.11
33		26.10	19.53	15.80	13.74	12.30	11.46	10.82
34		25.78	19.22	15.52	13.47	12.05	11.19	10.54
35		25.50	18.94	15.27	13.23	11.85	10.94	10.28
36		25.31	18.73	15.07	13.01	11.74	10.71	10.05

The Situation

A logger is preparing to bid on approximately 100,500 board feet of oak-hickory sawtimber offered for sale in a 54-acre tract in Jack's Hollow. Approximately 39,000 board feet of the timber to be cut is on good sites where 10 trees per acre (average) are marked for harvest. The trees average 20 inches in diameter, 2 logs in merchantable height, and 300 board feet in gross volume. Cut per acre on this part of the tract will average about 3,000 board

feet. In the remainder of the tract, about 61,500 board feet will be cut on poorer sites where the trees average 18 inches in diameter, 1½ logs in height, and about 190 board feet in gross volume. An average of 8 trees, or about 1,500 board feet per acre, is marked for cutting on this part of the tract.

The logger pays his felling and bucking crews by the hour, and furnishes all the equipment and fuel they use. For a one-man crew the pay is $1.75 per hour, with a 10-minute rest included in each hour.

The Problem

In preparing his bid for the Jack's Hollow timber, how much should the logger allow for the cost of log-making?

If his bid is successful and he purchases the timber, how many crew-hours should the logger allow for completing the log-making operation?

The Solution

Complete a *Log-Making Appraisal Work Sheet* (fig. 5) as described below:

Part A: Reference Data

Item 1. — The Jack's Hollow tract is considered a Logging Chance. A Logging Chance is a sale area, a drainage, a group of small timber tracts, or any other area that a logger considers to be one job. Jack's Hollow is located in Section 16, Township 5 South, Range 8 East.

Item 2. — Log-making cost appraisals may be made for either one-man or two-man crews. In this case the appraisal is for a one-man crew.

Items 3, 4, 5, and 6. — When the data needed to complete these items are not available from a cruise of the tract or from a prospectus, the logger must estimate them. If average tree size and volume cut per acre differ greatly from one part of the tract to another, the accuracy of the log-making estimate can be increased by subdividing the tract into Logging Units. For the purpose of log-making appraisals a Logging Unit is an area within a

FIGURE 5. — Log-Making Appraisal Work Sheet.

LOG-MAKING APPRAISAL WORK SHEET

A. REFERENCE DATA:

1. Logging Chance: Jack's Hollow (Name) : Sec. 16, T. 55, R. 8E. (Location)
2. Number of men in log-making crew: 1
3. Number of Logging Units: 2
4. Logging Unit size, and number of trees and volume cut per acre:
   - Logging Unit No. 1; 13 acres; 10 trees/acre; 3,000 bd. ft./acre
   - Logging Unit No. 2; 41 acres; 8 trees/acre; 1,500 bd. ft./acre
   - Logging Unit No. –; – acres; – trees/acre; – bd. ft./acre
   - Total acres: 54
5. Average tree size:
   - Logging Unit No. 1; 20 inches d.b.h.; 2 logs
   - Logging Unit No. 2; 18 inches d.b.h.; 1 1/2 logs
   - Logging Unit No. –; – inches d.b.h.; – logs
6. Volume to be cut:
   - Logging Unit No. 1; 39,000 board feet
   - Logging Unit No. 2; 61,500 board feet
   - Logging Unit No. –; – board feet
   - Total board feet: 100,500

B. PRODUCTION DATA:

	Time in crew-minutes per M bd. ft.		
	Logging Unit No. 1	Logging Unit No. 2	Logging Unit No. 3
7. Travel between trees	2.52	4.51	–
8. Fell, limb and mark, buck	29.23	38.07	–
9. Maintenance	12.00	12.00	–
10. Total production time	43.75	54.58	–

11. Minutes worked per hour (average for all Units): 50
12. Volume produced per hour[1]:
    - Logging Unit No. 1: 1,143
    - Logging Unit No. 2: 916
    - Logging Unit No. 3: –

C. COST ANALYSIS AND CONCLUSIONS:

13. Fixed costs per hour for all Logging Units: $2.80

14. Fixed costs per M bd. ft.[2]	$ 2.45	$ 3.06	–
15. Operating costs per M bd.ft.	.45	.45	–
16. Total cost per M bd. ft.	$ 2.90	$ 3.51	–
17. Cost per Logging Unit[3]	$113.10	$215.86	–

18. Total cost for all Logging Units: $328.96
19. Conclusions: Total log-making cost for tract - about $330. Cost per M bd. ft. produced - about $3.30. If two one-man crews are put on the tract, production per day should average about 16,000 bd. ft. Completing the log-making operation would require about 101 crew-hours, or about 6 1/3 days for two crews.

1/ Line 11 divided by line 10 times 1,000.
2/ Line 13 divided by line 12 times 1,000.
3/ Line 6 times line 16 divided by 1,000.

Logging Chance where the volume cut per acre and average size of the trees to be cut are similar. Where an area of 5 acres or more differs from the remainder of the Logging Chance by 500 board feet or more in average cut per acre, or by 50 board feet in average tree volume, that area should be considered as a separate Logging Unit.

To obtain log-making costs it is necessary to have an estimate of average tree size for each Logging Unit, the acreage of each Unit, and the number of trees to cut in each. It may be necessary to examine the timber in the Logging Units to obtain some of this information. Oftentimes the total volume to be cut is known and number of trees designated or marked for cutting can be counted or, for large tracts, determined by sample counts in each Unit. Acreage of each Logging Unit should be determined or estimated to the nearest whole acre, average tree diameter to the nearest full inch, merchantable height to the nearest half log, and volume per acre to the nearest 100 board feet. As a check, the volume to cut per acre times the acreage of the Logging Unit should approximate the volume to be cut in the Unit.

The Jack's Hollow Logging Chance is divided into two Logging Units. In one Unit there are 13 acres; the trees to be cut average 20 inches in diameter and 2 logs in merchantable height. There is an average of 10 trees, or 3,000 board feet, per acre to cut. In the other Unit there are 41 acres; the trees to be cut average 18 inches in diameter and 1½ logs in height. Eight trees, or 1,500 board feet, per acre are to be harvested. The first Unit contains approximately 39,000 board feet of marked timber, and the second Unit 61,500 board feet; a total of about 100,500 board feet for the Logging Chance (see *The Situation*).

The *Log-Making Appraisal Work Sheet* provides space to enter data for three Logging Units. If the Logging Chance contains more than three Logging Units, use additional work sheets, but otherwise proceed in the same manner as for a Logging Chance with three or less Units.

Part B: Production Data

Item 7. — Refer to table 1, page 10. For Logging Unit No. 1, average cut per acre is 10 trees and 3,000 board feet, and so travel time is 2.52 man-minutes per thousand board feet. For Logging Unit No. 2, average cut per acre is 8 trees and 1,500 board feet, and so travel time is 4.51 man-minutes per thousand board feet.

Item 8. — Refer to table 3, page 12. For Logging Unit 1 the time estimate to fell, limb and mark, and buck trees 20 inches in diameter and 2 logs in height is shown as 29.23 crew-minutes per thousand board feet. Similarly, for Logging Unit No. 2 with 18-inch, 1½-log trees, estimated time is 38.07 crew-minutes per thousand board feet.

Item 9. — For the study described in this report, maintenance time for one-man crews averaged 12.00 crew-minutes per thousand board feet felled and bucked and was not affected significantly by tree size, volume cut per acre, rate of production, or other variables measured. This maintenance time will be used for the Jack's Hollow felling and bucking cost estimate.

Item 10. — Sum Items 7 through 9 for each column to obtain total production time per thousand board feet for each Logging Unit.

Item 11. — Enter here the number of minutes per hour the crew is expected to be actively engaged in log-making. This may vary with the experience and physical condition of the crew, weather, and other factors. The production tables included in this report are based on performance by crews that took a 10-minute break every hour and maintained a steady productive work pace between breaks. For this example, it is assumed that the work will follow a similar pattern and the one-man crew will average about 50 working minutes per hour.

Item 12. — For each Logging Unit, divide Item 11 by Item 10 and multiply by 1,000.

Part C: Cost Analysis and Conclusions

Item 13. — Enter the sum of hourly wages, including related costs such as workman's compensation and insurance, overhead expense, and other cost items not directly related to the volume of timber felled and bucked. These costs will vary among areas; but for this example, $2.80 per hour is used for both Logging Units.

Item 14. — The fixed cost per thousand board feet is obtained by dividing the entry on line 13 by the volume produced per hour, as entered on line 12, and multiplying by 1,000.

Item 15. — Operating costs are directly related to the volume produced and are charged on a per-thousand-board-foot basis. Included are depreciation of the equipment, fuel, lubrication, off-the-job repair, and replacement of parts. For example, the residual

value of a powersaw depends chiefly upon how much it has been operated or how much volume was cut with it, rather than its age. Similarly, fuel consumption, wear of the chain, and need for lubrication and maintenance increase as use of the saw increases. Obviously, these costs will vary depending upon original cost of equipment, expected useful life, cost of fuel, rates for maintenance, and other factors. For this example, $0.45 per thousand board feet is used as an estimate of operating costs.

Item 16. — Enter the sum of Items 14 plus 15 for each Logging Unit.

Item 17. — To determine the cost for each Logging Unit, multiply the entry in Item 16 by the entry in Item 6 and divide by 1,000.

Item 18. — The log-making cost for the Logging Chance is the sum of the entries in Item 17.

Item 19. — Use this space to summarize important results of the appraisal for easy reference. Include such information as the total estimate of log-making costs for the tract, the overall cost per thousand board feet produced, the number of crews required to achieve the daily production needed, and the number of days these crews will require to complete their work on the tract.

Further Considerations

In this case the entries for Item 19 might be as follows:

> Total log-making cost for the tract — about $330. Cost per thousand board feet produced — about $3.30. If two one-man crews were put on the tract, production per day should average 16,000 board feet. Completing the log-making would require about 101 crew-hours, or about 6⅓ days for two crews.

The amount shown in Item 18 reflects log-making production rates achieved by crews trained to follow a set sequence of steps in completing the log-making operation, and to operate at a level of proficiency considered to be representative of well-trained commercial crews of the Central Hardwood area. As a result, it is to be expected that some commercial crews will exceed the rate of production indicated by the Appraisal Work Sheet; others will fall below it. As loggers gain experience using the work sheet, most will

find that they can improve their log-making cost estimates by providing for production characteristics peculiar to their individual operations.

Appraisals similar to the one illustrated for Jack's Hollow can be made for both one- and two-man crews and a wide variety of logging conditions. These appraisals enable the logger to assign available men and equipment so that log-making is balanced with skidding and other logging operations, and needed log-production rates are maintained at the lowest possible cost.

For most of the conditions covered in the study described here, log-making production per hour by two-man crews exceeded that by one-man crews by less than 30 percent. For that reason use of the *Log-Making Appraisal Work Sheet* will always indicate a significant cost advantage for one-man crews unless the men on the two-man crews are available at a lower average hourly wage rate than one man working alone. However, from both a safety and production viewpoint, one-man crews should be used only if assigned to work within hailing distance of prompt assistance in case of an accident or a problem in log-making that could be handled more easily and safely by two men. For these reasons, assigning two or more one-man log-making crews to work in the same area often provides both the advantage of one-man crew efficiency and two-man safety.

THE AUTHORS

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The Forest Service of the U.S. Department of Agriculture is dedicated to the principle of multiple use management of the Nation's forest resources for sustained yields of wood, water, forage, wildlife, and recreation. Through forestry research, cooperation with the States and private forest owners, and management of the National Forests and National Grasslands, it strives — as directed by Congress — to provide increasingly greater service to a growing Nation.